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Acute resistance exercise with blood flow restriction in elderly hypertensive women: haemodynamic, rating of perceived exertion and blood lactate

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Summary

Purpose This study aimed to compare haemodynamic, rating of perceived exertion and blood lactate responses during resistance exercise with blood flow restriction (BFR) compared with traditional high-intensity resistance exercise in hypertensive older women.

Methods Eighteen hypertensive women (age = 67·0 ± 1·7 years.) undertook three random sessions: (i) three sets; 10 repetitions; 20% of one repetition maximum (1RM) with BFR; (ii) three sets; 10 repetitions; 65% of 1RM; without BFR; and (iii) no-exercise with BFR. The exercise sessions were performed on knee extension equipment.

Results Systolic (SBP) and diastolic blood pressure (DBP), heart rate (HR), stroke volume (SV) and cardiac output (CO) were significantly higher ($P<0·05$) in all sets of exercise sessions than the control. No statistically significant differences were detected between exercise sessions. However, SBP, DBP and systemic vascular resistance were higher ($P<0·05$) and SV and CO were lower ($P<0·05$) during the rest intervals in the session with BFR. The perceived exertion was significantly higher ($P<0·01$) in the 1st (4·8 ± 0·4 versus 3·1 ± 0·3), 2nd (7·3 ± 0·4 versus 5·7 ± 0·4) and 3rd sets (8·6 ± 0·5 versus 7·5 ± 0·4) of the traditional high-intensity resistance exercise compared with the exercise with BFR. Blood lactate was higher ($P<0·05$) in the traditional high-intensity resistance exercise (6·2 ± 0·7 mmol) than in the exercise with BFR (4·5 ± 0·4 mmol).

Conclusion In comparison with high-intensity resistance exercise, low-intensity resistance exercise with BFR can elicit: (i) same haemodynamic values during exercise; (ii) lower rating of perceived exertion; (iii) lower blood lactate; (iv) higher haemodynamic demand during the rest intervals.

Introduction

The traditional model of resistance training (>70% of one repetition maximum, 1RM) is indicated for the development of muscle strength and lean body mass in healthy adults (Garber *et al.*, 2011). Particularly in the elderly and individuals with systemic arterial hypertension, increased muscle strength has been associated with improved functional capacity (Sharman & Stowasser, 2009; Villanueva *et al.*, 2015) and lower cardiovascular overload during daily life activities (Sale *et al.*, 1994). However, both hypertensive individuals and the elderly may present limitations to perform this traditional model of training, which can cause abrupt increases in blood pressure during the exercises (Nery *et al.*, 2010), inducing an increased risk of cardiac events (Haykowsky *et al.*, 1996).

In this context, a low-intensity resistance exercise model (≤20% 1-RM), associated with blood flow restriction (BFR) has provided chronic improvement in muscle strength and lean body mass in healthy subjects (Loenneke *et al.*, 2012; Slysz *et al.*, 2015), as well as lower cardiovascular response compared with high-intensity resistance exercise (Poton & Polito, 2014). Therefore, considering that cardiovascular response is directly related to the load (Palatini *et al.*, 1989), some studies suggest that a BFR model could be an alternative for the abovementioned populations (Scott *et al.*, 2015).

Despite the chronic effects of resistance training with BFR on muscle strength, some acute effects of this type of training are still not clear, especially cardiovascular responses, which are not reported in a consensual manner in the literature. For example, Vieira *et al.* (2013) found no differences in haemodynamic responses of young adults and the elderly submitted to biceps curl exercise with 30% of 1RM with and without BFR. However, in this study, the absence of a high-intensity session made it impossible to infer whether cardiovascular responses to BFR are of lesser or greater magnitude in comparison with the conventional model. Recently, a study found that cardiovascular responses in hypertensive women during the leg-press exercise with BFR (three sets; 15 reps; 30-s rest interval between sets; 20% 1RM) were higher than in the same exercise at high-intensity without BFR (three sets; eight reps; 60-s rest interval between sets; 65% 1RM) (Pinto & Polito, 2015). These data suggest that resistance exercise with BFR could increase the cardiovascular response in hypertensive subjects. However, some questions remain unanswered. Firstly, fifteen repetitions were performed in the session with BFR (almost twice the time to execute compared with the session without BFR), and it is known that the blood pressure increases according to the number of repetitions, even with low load (Sale *et al.*, 1993; Polito *et al.*, 2007). Secondly, the low rest interval between sets is associated with high cardiovascular response during resistance exercise (Castinheiras-Neto *et al.*, 2010). Thirdly, the effects of BFR alone (without exercise) are unknown in hypertensive subjects as well as its effects on cardiovascular response.

It is not clear how much of the differences in haemodynamics following resistance training exercise sessions with and without BFR are due to the variations in number of repetitions and/or rest interval. In addition, traditional resistance training exercise recommendation for hypertensive subjects is lower in intensity/volume compared with the recommendation for healthy people (Pescatello *et al.*, 2004). It was important to examine the effects of low volume and load with BFR on the haemodynamic responses, which could be more manageable to be performed by special populations (such as hypertensive individuals). In this sense, the objective of this study was to compare the cardiovascular responses during BFR alone or in combination with resistance exercises, performed with different loads, but the same number of sets, repetitions and rest interval time in elderly women with systemic arterial hypertension.

Methods

Subjects

This study included 18 women, over 60 years of age, sedentary, with a diagnosis of hypertension, which was controlled by the same class of medication (angiotensin II receptor) without target organ damage. Prior to performing the exercises, the sample was subjected to a clinical examination consisting of an electrocardiogram (rest and effort) and an orthopaedic examination to confirm their clearance for the exercise sessions. The following were considered as exclusion criteria: a body mass index >35 kg m^{-2}, electrocardiographic alterations at rest or during effort, musculoskeletal problems that contraindicated performing the exercises, participation in leisure physical activity programmes more than twice a week and resting systolic blood pressure ≥160 mmHg and/or diastolic blood pressure ≥100 mmHg, prior to the exercise protocols. Table 1 illustrates the general characteristics of the sample.

During the study, the participants were instructed to eat a meal at least 2 h before the start of the exercise sessions, avoid alcohol and caffeine ingestion for 24 h prior to the test and refrain from exhaustive physical activities for 48 h. The experimental test occurred between 2 pm and 4 pm. All participants were volunteers and signed a written informed consent after being given explanations about the aim and methodology involved in the study. The ethics committee for research in humans of the Londrina State University (PR, Brazil), number 169/2013, approved the study.

Experimental design

The subjects underwent five non-consecutives visits to the laboratory (48-h intervals between days) in a randomized cross-over design. On the first 2 days, cardiovascular measures at rest were carried out (systolic and diastolic blood pressure) and the test and retest of 1RM performed (bilateral knee extension), in addition to adaptation to the subjective perception of effort and performing the exercises (with and without BFR). For the exercise adaptation, 10 repetitions were performed without load. On the other days, participants performed three randomized sessions (one control and two experimental sessions). In the control session (CON), the subject was positioned on the exercise equipment and BFR applied (without exertion) during the same time to complete

Table 1 Subjects characteristics and baseline data.

Variables	Subjects (n = 18)
Age (years)	67·0 ± 1·7
Weight (kg)	73·8 ± 3·3
Height (cm)	157·4 ± 1·5
Body mass index (kg m^{-2})	29·5 ± 1·2
Resting systolic blood pressure (mmHg)	120·2 ± 3·4
Resting diastolic blood pressure (mmHg)	69·3 ± 1·8
Resting heart rate (bpm)	78·4 ± 2·1
One repetition maximum (kg)	49·0 ± 2·5
100% of blood flow restriction (mmHg)	177·8 ± 5·9
80% of blood flow restriction (mmHg)	143·7 ± 4·8
Serum glucose (mg dl^{-1})	107·9 ± 7·5
Triglycerides (mg dl^{-1})	130·3 ± 17·5
Total cholesterol (mg dl^{-1})	183·1 ± 6·5
LDL cholesterol (mg dl^{-1})	99·7 ± 7·9
HDL cholesterol (mg dl^{-1})	66·8 ± 9·7
Drugs	
Angiotensin II receptor antagonists	12
Angiotensin II receptor antagonists + diuretic	6
Others diseases	
Type 2 diabetes	2
Hypothyroidism	3
Type 2 diabetes + hypothyroidism	4

the exercise session. During testing sessions, the bilateral knee extension exercise was executed on knee extensor chair equipment (three sets, 10 reps; 1-min interval between sets). In one of the experimental sessions, the exercise was performed with BFR and 20% 1RM (LI-BFR); while in the other experimental session, the exercise was performed without BFR and 65% 1RM (HI-RE). The range of motion was visually defined, starting at 90° and finishing at 180°. Each phase of the movement (concentric and eccentric) in the experimental sessions lasted for 2 s, with the aid of a metronome, totalling 4 s per repetition, 40 s per set and 4 min per session (effort time plus recovery interval). Accordingly, the BFR time in the control session was also 4 min. In all sessions, the participants were advised to maintain normal breathing in order to avoid the Valsalva manoeuver. Haemodynamic variables were obtained by with continuous and non-invasive digital photoplethysmography device during control and experimental sessions; blood lactate was obtained before and within 2–3 min after each experimental and control session; and rating of perceived exertion was obtained after experimental sessions.

Resting blood pressure measurement

Omron digital equipment (model HEM-742; Bannockburn, IL, USA) was used to measure blood pressure on the first and second visits. After the subjects had remained seated comfortably for 10 min, blood pressure was measured three times consecutively in the dominant arm, with a minimum interval of at least 1 min between measurements. The resting blood pressure was considered as the mean of the three measurements. The same evaluator performed all measurements. The blood pressure measurement was conducted in accordance with the American Heart Association (Pickering *et al.*, 2005).

One repetition maximal test

On the first day of testing, after the resting blood pressure measurement, the participants performed a warm-up on the extensor chair exercise (Technogym™, Rome, Italy) of 10 repetitions with no load in the bilateral knee extension movement. After 2–3 min, the load was increased and the sample was instructed to perform two repetitions. The load was progressively increased until the volunteer was able to complete one repetition, but unable to complete the second repetition. A maximum of five attempts was allowed at each load with a minimum 3-min interval between them. On the second day, the same procedure was followed and the 1RM was considered as the highest value obtained on both days. The participants were advised not to perform the Valsalva manoeuver.

Blood flow restriction

The BFR value was determined before each CON and LI-BFR sessions. A cuff (width = 18 cm, length = 90 cm) was placed below the inguinal fold on each thigh of the participants. A vascular *Doppler* device (Martec DV600; São Paulo, SP, Brazil) was positioned on the posterior portion of the medial malleolus on the branches of the tibial artery. The cuffs were inflated until the interruption of sound from the *Doppler* and the cuff values recorded (in mmHg). The *cuff* pressure used in the exercise with BFR was stipulated as 80% of the necessary pressure for full blood interruption. The BFR cuffs were inflated just before exercises and remained inflated during the entire exercise and rest intervals between sets. On the first 2 days of data collection, the participants underwent an exercise protocol with BFR but without load, for the purposes of adaptation to movement with the cuffs.

Haemodynamic measurement during exercise and control sessions

The experimental and control sessions were performed with continuous, non-invasive cardiovascular monitoring using a digital photoplethysmography device (Finometer™ PRO; Finapres Medical System, Amsterdam, The Netherlands). Penaz (1973) originally described this technique, which is based on the volume-clamp principle of the arterial walls. An adapted pneumatic cuff is placed on the medial finger of the left hand and inflated until the pulse in the digital artery is sensed. The pneumatic regulation is adjusted simultaneously by a servo-controlled system that keeps the digital artery volume constant by varying the cuff pressure proportionally, thus providing continuous blood pressure readings. From the blood pressure readings, the equipment uses algorithms to estimate other variables, such as heart rate (HR), stroke volume (SV), cardiac output (CO) and systemic vascular resistance (SVR).

After the subjects had been positioned on the equipment, a cuff was attached to the middle finger of the left hand, with the arm relaxed and supported on a stable surface. The equipment performs its own calibration, and this routine was applied for 10 min prior to the exercise or control sessions. The variables analysed were systolic blood pressure (SBP), diastolic blood pressure (DBP), HR, SV, CO and SVR. The values set for the variables were as follows: (i) highest value measured during the set; (ii) minimum value measured during the recovery intervals; (iii) average of 5 min before the exercise and after the 3rd rest interval. Data were transmitted to a portable computer using specific software (BeatscopeEasy™, Finapres Medical System).

Blood lactate

Blood lactate was obtained before and within 2–3 min after each experimental and control session. Prior to collection of the blood sample, asepsis was performed with 70% ethylic solution on the distal portion of the fingertip from the middle finger of the right hand. The puncture was performed using disposable lancets, a suspended drop of blood being applied to a specific area on a BM-lactate test strip which was analysed by a portable lactometer (Roche™ AccutrendPlus, New York, NY, USA).

Rating of perceived exertion

After each exercise session, participants were asked to score their rating of perceived exertion (scale CR-10) (Borg, 1998). The participants had been previously instructed on the use of this scale during their first and second visits.

Statistical analyses

The data are presented as mean and standard error. Initially, the Gaussian distribution was assessed using the Shapiro–Wilk test and the homogeneity of variance was assessed using Levene's test. Two-way repeated-measures ANOVA (sessions x sets) was used to compare the variations in SBP, DBP, HR, SV, CO and SVR at different moments: (i) at rest; (ii) during the sets; (iii) during the rest intervals between sets; (iv) at the end of each session. Two-way ANOVA with repeated measures was also used to verify differences in ratings of perceived exertion. A one-way ANOVA was used to verify the differences in the blood lactate values. Fisher LSD *post hoc* analyses were applied to identify the differences in cases where the F values were higher than the established criteria for one-tailed statistical significance ($P<0·05$). The data were analysed using Statistica software (version 10; Statsoft™, Tulsa, OK, USA).

Results

Cardiovascular responses during exercise sessions

The values of the cardiovascular variables during the exercise sessions are described in Table 2. For the CON session, the BFR in isolation caused a significant increase in DBP and SVR between the resting value and the equivalent moments in the 1st, 2nd and 3rd sets. Similarly, there was a significant reduction in SV and CO between the resting value and the other sets. After the complete liberation of blood flow, the SVR and DBP values were significantly lower than those in the three sets, while the CO value was higher than the values in the three sets. For the LI-BFR session, there was a significant increase between the rest value and the three sets for SBP, DBP, HR and SVR. The CO was greater than the rest value only in the 1st set. After the end of the exercises and the discontinuation of BFR, the values of SBP and DBP were significantly lower than in the three sets, while the HR, SV and CO values were lower for the three sets and also in relation to the resting value. For the HI-RE session, all the variables increased significantly in the three sets in relation to the rest value. After the end of the session, the values of SBP, DBP and HR were significantly lower than during the three sets. The SV and CO values were lower than during the three sets and also in relation to the rest value. On the other hand, the SVR value remained higher than the resting value.

The comparison between sessions demonstrated no significant differences between the rest values, the sets and the postexercise values for the LI-BFR and HI-RE sessions. On the other hand, the variables SBP, DBP, HR, SV and CO were significantly higher in all sets of the LI-BFR and HI-RE sessions when compared with the CON session. Furthermore, differences were observed in the postexercise variables of HR, CO and SVR between the CON session and the other sessions; in the postexercise SV between the CON and LI-BFR sessions; and in the 2nd and 3rd sets of SVR between the CON and LI-BFR sessions.

Table 2 Haemodynamic responses during different sessions.

SESSION		SBP (mmHg)	DBP (mmHg)	HR (bpm)	SV (ml)	CO (l min^{-1})	SVR (mmHg min l^{-1})
Control (BFR without exercise)	Resting	134·3 ± 3·6	74·1 ± 1·7†	78·6 ± 2·7	57·1 ± 3·8†	4·5 ± 0·4†	22·3 ± 2·1†
	1st set	143·2 ± 5·7*	81·2 ± 3·1*	78·6 ± 2·4*	51·0 ± 3·9*	4·0 ± 0·3*	28·0 ± 3·3
	2nd set	139·7 ± 4·9*	81·3 ± 2·8*	81·2 ± 2·5*	46·9 ± 3·4*	3·8 ± 0·3*	29·5 ± 3·5§
	3rd set	140·2 ± 4·9*	81·3 ± 2·8*	81·5 ± 2·4*	47·2 ± 3·9*	3·9 ± 0·4*	29·2 ± 3·6§
	Postexercise	133·7 ± 4·4	75·7 ± 2·3†	82·9 ± 2·4*	53·1 ± 4·2§	4·4 ± 0·4*†	23·6 ± 2·4*†
20% of 1RM with BFR	Resting	132·7 ± 3·1†	76·0 ± 2·3†	80·2 ± 3·0†	54·5 ± 4·0	4·3 ± 0·3	24·8 ± 2·3†
	1st set	179·8 ± 5·4	100·9 ± 3·2	96·1 ± 2·6	57·7 ± 4·5	5·1 ± 0·4‡	29·0 ± 3·0
	2nd set	210·7 ± 6·8	120·9 ± 4·5	99·8 ± 3·2	53·9 ± 4·6	4·9 ± 0·5	36·0 ± 3·6
	3rd set	212·2 ± 7·5	123·6 ± 5·5	97·9 ± 2·9	50·8 ± 4·6	4·6 ± 0·5	41·3 ± 5·2
	Postexercise	129·8 ± 2·9†	74·2 ± 2·5†	73·7 ± 2·0†‡	37·2 ± 3·3†‡	3·1 ± 0·3†‡	35·2 ± 3·7
65% of 1 RM	Resting	130·3 ± 4·2†	73·2 ± 1·8†	78·9 ± 2·8†	54·5 ± 2·9†	4·3 ± 0·2†	22·9 ± 1·4†
	1st set	196·8 ± 7·1	108·8 ± 3·5	100·9 ± 3·7	63·5 ± 3·7	5·7 ± 0·4	26·6 ± 2·0
	2nd set	213·3 ± 8·2	119·5 ± 4·5	102·9 ± 3·4	66·3 ± 5·4	6·0 ± 0·5	28·7 ± 2·6
	3rd set	221·7 ± 8·2	122·6 ± 3·9	107·8 ± 4·0	63·7 ± 4·2	6·1 ± 0·5	28·8 ± 2·7
	Postexercise	138·5 ± 5·9†	71·1 ± 2·4†	74·7 ± 3·4†	44·3 ± 3·6†‡	3·6 ± 0·3†‡	31·1 ± 3·5‡

SBP, systolic blood pressure; DBP, diastolic blood pressure; HR, heart rate; SV, stroke volume; CO, mcardiac output; SVR, systemic vascular resistance.
*Significant difference to 20% of 1RM with BFR and 65% of 1RM (same set).
†Significant difference ($P<0·05$) from 1st to 3rd set (same session).
‡Significant difference ($P<0·05$) to rest (same session).
§Significant difference to 20% of 1RM with BFR (same set).

Cardiovascular responses during rest intervals between sets

Table 3 presents the values of the haemodynamic variables during the rest intervals between the sets (from the 1st to 2nd set and from the 2nd to 3rd set). In this context, there was an increase from the 1st to the 2nd rest interval in the variables SBP, DBP and SVR, and a reduction in SV and CO. The comparison between sessions demonstrated differences in the 1st rest interval between the CON session and LI-BFR session (SV, CO and SVR), between the CON session and HI-RE session (DBP, SV and CO) and between the LI-BFR session and HI-RE session (SV, CO and SVR). For the 2nd rest interval, differences were observed between the LI-BFR session and the CON session (SBP, DBP, SV, CO and SVR), between the CON session and the HI-RE session (DBP, SV and CO) and between LI-BFR session and the HI-RE session (SBP, DBP, SV, CO and SVR).

Rating of perceived exertion

The perceived exertion response was significantly higher ($P<0{\cdot}01$) in the 1st (4·8 ± 0·4 versus 3·1 ± 0·3), 2nd (7·3 ± 0·4 versus 5·7 ± 0·4) and 3rd sets (8·6 ± 0·5 versus 7·5 ± 0·4) of the HI-RE session compared with the LI-BFR.

Blood lactate

The values of blood lactate are shown in Figure 1. Both exercise sessions exhibited significantly higher values than the CON session. In addition, the HI-RE session demonstrated significantly higher values than the LI-BFR session.

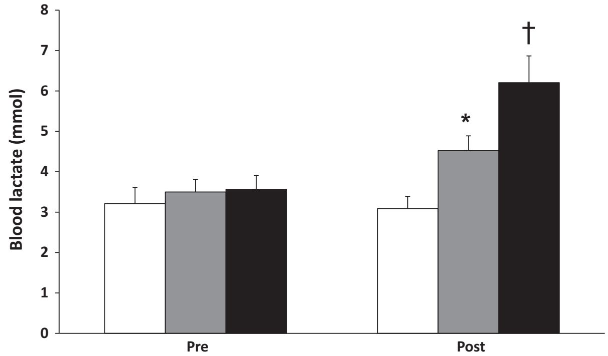

Figure 1 Blood lactate at rest (Pre) and after (Post) resistance exercise with or without blood flow restriction. White column: control session (CON); grey column: resistance exercise with blood flow restriction (LI-BRF); dark column: resistance exercise without blood flow restriction (HI-RE). * significant difference to CON (<0·05); † significant difference to CON and LI-BFR ($P<0{\cdot}05$).

Discussion

The main findings of this study were as follows: (i) in isolation, BFR increased the SVR and DBP values and reduced the SV and CO values when compared with the rest value; (ii) haemodynamic responses during resistance exercise, independent of BFR, increased when compared with the at rest condition; (iii) during the rest intervals between sets, the exercise with BFR demonstrated increases in SBP, DBP and SVR, and decreases in SV and CO compared with the exercise without BFR.

In healthy young subjects, BFR without exercise did not significantly alter the SBP or DBP responses (Loenneke *et al.*, 2013). However, the present study demonstrated that the haemodynamic responses behave differently in elderly hypertensive subjects. One possible explanation for these results could be based on the fact that hypertensive individuals present abnormally large reflex-mediated increases in sympathetic activity during blood flow occlusion after isometric exercise (Greaney *et al.*, 2014). This type of manoeuver is used to analyse the metaboreflex response and can cause increases in SVR and reductions in SV (Kim *et al.*, 2015). For the reductions identified in SV and CO, it is assumed that the pressure applied by the BFR was a key factor in the reduction of venous return by trapping the blood in the active limbs and influencing the responses of these variables.

Table 3 Haemodynamics response values during pauses between sets.

Session		SBP (mmHg)	DBP (mmHg)	HR (bpm)	SV (ml)	CO (l min^{-1})	SVR (mmHg min l^{-1})
Control	1st rest interval	141·4 ± 5·7	81·4 ± 3·0	80·1 ± 2·6	55·0 ± 6·3	4·4 ± 0·5	29·1 ± 3·3
(BFR without exercise)	2nd rest interval	139·4 ± 5·1	80·8 ± 2·9	81·9 ± 2·4	55·2 ± 6·7	4·5 ± 0·5	28·7 ± 3·4
20% of 1RM with BFR	1st rest interval	140·4 ± 3·6	78·2 ± 1·7	76·7 ± 2·3	40·3 ± 3·5†‡	3·4 ± 0·3†‡	34·7 ± 3·7†‡
	2nd rest interval	155·3 ± 5·1*†‡	86·8 ± 3·5*†‡	76·4 ± 2·6	34·4 ± 3·2*†‡	2·9 ± 0·3*†‡	44·5 ± 4·8*†‡
65% of 1RM	1st rest interval	140·3 ± 6·0	72·4 ± 2·3†	78·7 ± 2·6	46·7 ± 3·4†	3·9 ± 0·3†	28·0 ± 2·9
	2nd rest interval	138·5 ± 5·9	71·1 ± 2·4†	74·7 ± 3·9	44·3 ± 3·6†	3·6 ± 0·3†	33·1 ± 3·5

SBP, systolic blood pressure; DBP, diastolic blood pressure; HR, heart rate; SV, stroke volume; CO, cardiac output; SVR, systemic vascular resistance.
*Significant difference ($P<0{\cdot}05$) to 1st rest interval (same session).
†Significant difference ($P<0{\cdot}05$) to control session (same rest interval).
‡Significant difference ($P<0{\cdot}05$) to 65% of 1 RM (same rest interval).

During resistance exercise, cardiovascular modifications occur due to an increase in sympathetic activity (Seals, 1993), compression of the blood vessels by the muscles involved (Palatini *et al.*, 1989) and muscle contraction (MacDougall *et al.*, 1992). In this context, even at relatively light loads (i.e. 20% 1RM), there is a significant increase in SBP and DBP during exertion (Poton & Polito, 2014). However, little information exists regarding cardiovascular responses during resistance exercise with BFR. In healthy young people, resistance exercise without BFR (three sets; eight reps; 80% 1RM; 1 min of resting interval) demonstrated significantly higher values of SBP and DBP during exertion than the exercise with BFR (three sets; 20 reps; 20% 1RM; 45 s rest interval). On the other hand, recent data in a hypertensive sample demonstrated significantly higher values during the haemodynamic resistance exercise with BFR (three sets; 15 reps; 20% 1RM; 30 s of resting interval) when compared with traditional resistance exercise (three sets; eight reps; 65% 1RM; 1-min rest interval) (Pinto & Polito, 2015). The greater responsiveness of hypertensive individuals may be related to the fact that this population presents a greater likelihood of endothelial dysfunction (Guazzi *et al.*, 2005) and a greater haemodynamic response during sympathetic activation (Kaushik *et al.*, 2004). Independent of the differences between hypertensive and normotensive individuals, the studies of Poton & Polito (2014) and Pinto & Polito (2015) used different quantities of repetitions and rest intervals between sessions with and without BFR. In this context, the session with BFR had a greater number of repetitions and a shorter rest interval than the traditional session, which may have contributed to these differences (Polito *et al.*, 2007). In the present study, the application of BFR during exercise did not affect the cardiovascular behaviour of the elderly hypertensive participants, suggesting that the equalization of volumes and recovery times is a factor that should be considered when prescribing exercise.

During the recovery interval, the high values found during exercise are expected to decrease (Wiecek *et al.*, 1990). This behaviour was observed in the HI-RE session, and for this reason, no differences were identified between the HI-RE and CON sessions for SBP, HR or SVR. In addition, significant reductions were identified in DBP. The only significant alterations between the HI-RE and CON occurred in SV and CO. In this case, there was a decrease in both variables in the recovery intervals of the HI-RE session. This can be explained by the high blood concentration in the lower limbs during exertion, which is not fully re-established within a short interval (Polito *et al.*, 2004). On the other hand, the maintenance of the BFR in the LI-BFR session lead to significant increases in relation to the HI-RE session in the second rest interval for SBP and DBP; significant reductions in both intervals for SV and CO; and significant increases in both intervals for SVR. These results support the hypothesis that hypertensive individuals exhibit abnormally large reflex-mediated increases in sympathetic activity during blood flow occlusion (Greaney *et al.*, 2014). In this case, after the end of each set in the LI-BFR session, the maintenance of BFR may have both stimulated the sympathetic activity and hindered the normal blood flow. In addition, it is possible that hypertensive individuals present endothelial dysfunction, which could explain the less pronounced decreases in the BP values after a large stimulus, considering the short duration of the effort (Kaushik *et al.*, 2004). We believe that this information is important in the practical application of the BFR exercise model. Independent of what happens during the exercise, the recovery period can also demand efforts from the cardiovascular system, as identified in the pauses between sets of the BFR exercises.

Concerning blood lactate and perceived exertion, there is a significant increase in the metabolic concentration (Suga *et al.*, 2009) and pain perception (Wernbom *et al.*, 2009) when BFR is associated with exercise. This was recently demonstrated (Pinto & Polito, 2015), in which the authors found that exercise with BFR (three sets, 15 reps, 20% 1RM) showed higher values of rating of perceived exertion and blood lactate than traditional exercise (three sets, eight reps, 65% 1RM without BFR). In this sense, the accumulation of lactate creates a more acid environment, which increases BP via muscle metaboreflex (29) and the pain perception caused by the inflated cuff and by the acid environment increases BP due to stimulation of the central nervous system (Chalaye *et al.*, 2013). However, data from the present study showed that rating of perceived exertion and blood lactate was higher in the HI-RE session than the LI-BFR session. One probable explanation is the fact that the LI-BFR session was performed with pressure lower than total blood occlusion and the number of repetitions (total exercise time) was equalized when compared with the HI-RE session. However, higher values of rating of perceived exertion and blood lactate observed in the HI-RE session did not reflect in greater cardiovascular responses in the LI-BFR session. Thus, other mechanisms must be acting during resistance exercise with BFR to cause major cardiovascular responses in hypertensive individuals, which should be investigated in future studies.

Concerning clinical significance, a rise in blood pressure can increase the risk of haemorrhagic events in hypertensive subjects (Haykowsky *et al.*, 1996). However, it is important to consider that these results may change according to the experimental design. When compared with traditional exercise, resistance exercise with BFR presents one additional variable: BFR. In this context, the cuff pressure and maintaining this pressure can be determining factors in cardiovascular behaviour during this type of effort.

In conclusion, low-intensity resistance exercise with BFR elicited the same haemodynamic and cardiovascular responses in hypertensive women as traditional high-intensity resistance training exercise and it could be more manageable to be performed by hypertensive individuals. As breath-holding (Valsalva manoeuver) is more likely with high-intensity resistance training exercise or when lifting lighter loads to failure (Hackett & Chow, 2013), BFR with low-intensity exercise can be used to prevent Valsalva manoeuver during resistance training programmes for the individuals with hypertension. However, higher haemodynamic and cardiovascular responses occurred during the rest interval between sets. In a brief perspective, our results are related to the design used in this study. Nevertheless, as no other studies have been conducted with a hypertensive sample, this model of low-intensity resistance exercise with BFR should be applied with caution in hypertensive subjects.

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Conflict of interest

The authors declare that they have no conflict of interests.

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